

CLAIMS

1. An article comprising:
a blow molded, foam, microcellular, polymeric article.
2. An article comprising:
an extruded, microcellular parison suitable for blow molding.
3. An article as in claim 1, having a void volume of at least about 10%.
4. An article as in claim 1, having a void volume of at least about 20%.
5. An article as in claim 1, having a void volume of at least about 30%.
6. An article as in claim 1, having a void volume of at least about 50%.
7. An article as in claim 1, having the appearance of an essentially solid, white plastic article.
8. An article as in claim 1, constructed as a container for food.
9. An article as in claim 1, constructed as a container for milk.
10. An article as in claim 1, containing food.
11. An article as in claim 1, containing milk.
12. An article as in claim 1, constructed and arranged to contain food.
13. An article as in claim 1, including residual chemical blowing agent or reaction by-product of chemical blowing agent in an amount less than that inherently found in articles

blown with about 0.1% by weight chemical blowing agent or more.

14. An article as in claim 1, including residual chemical blowing agent or reaction by-product of chemical blowing agent in an amount less than that inherently found in articles blown with 0.05% by weight chemical blowing agent or more.

15. An article as in claim 1, being essentially free of residual chemical blowing agent or free of reaction by-products of chemical blowing agent.

16. An article as in claim 1, having less than about 0.1 percent by weight auxiliary chromophore, constructed and arranged for containing material subject to destruction upon exposure to light.

17. An article as in claim 1, the article being free of a non-foam, structurally-supporting material positioned to support the foam article.

18. An article as in claim 1, comprising at least two blow-molded, foam, microcellular polymeric layers.

19. An article as in claim 18, comprising at least two co-extruded layers.

20. An article as in claim 1, comprising auxiliary non-foam, non-structurally-supporting layer adjacent the foam article.

21. An article as in claim 1, including at least one portion having a wall thickness of less than about 0.075 inch.

22. An article as in claim 1, wherein the article is a container and at least 50% of the container has a wall thickness of less than about 0.075 inch.

23. An article as in claim 1, wherein the article is a container and at least 50% of the

container has a wall thickness of less than about 0.050 inch.

24. An article as in claim 1, wherein the article is a container and at least 50% of the container has a wall thickness of less than about 0.040 inch.

25. An article as in claim 1, formed of polymeric material having melt flow of no more than about 0.2 g/10 min.

26. An article as in claim 1, including a first portion expanded to a first extent and a second portion expanded at least 1.5 times the first extent, the first and second portions differing in each of thickness, material density, and cellular density by no more than about 5%.

27. An article as in claim 1, including less than about 10 percent by weight reinforcing agent.

28. An article as in claim 1, having an average cell size of less than about 50 microns.

29. An article as in claim 1, having an average cell size of less than about 30 microns.

30. An article as in claim 1, having an average cell size of less than about 20 microns.

31. An article as in claim 1, having a maximum cell size of about 75 microns.

32. An article as in claim 1, having a maximum cell size of about 50 microns.

33. An article as in claim 1, having a maximum cell size of about 35 microns.

34. An article as in claim 1, having an average cell size of less than about 30 microns and a maximum cell size of about 75 microns.

35. An article as in claim 1, having an average cell size of less than about 20 microns and a maximum cell size of about 50 microns.
36. An article as in claim 1, having an average cell size of less than about 10 microns and a maximum cell size of about 25 microns.
37. An article as in claim 1, wherein the microcellular material is essentially closed-cell.
38. An article as in claim 1, including at least about 1% by weight nucleating agent.
39. An article as in claim 38, wherein the nucleating agent is talc.
40. An article as in claim 2, formed as an extruded parison suitable for blow molding, having a first portion and a second portion spaced from the first portion in a parison machine direction, the first portion and second portion differing in thickness by a factor of at least about 1.1.
41. An article as in claim 40, the first portion and second portion differing in thickness by a factor of at least about 1.3.
42. An article as in claim 40, the first portion and second portion differing in thickness by a factor of at least about 1.5.
43. An article as in claim 40, the first portion and second portion differing in thickness by a factor of at least about 1.7.
44. An article as in claim 40, the parison having a first portion and a second portion spaced from the first portion in a parison machine direction, the first portion and second portion differing in material density by a factor of at least about 1.1.
45. An article as in claim 44, the first portion and second portion differing in material

density by a factor of at least about 1.3.

46. An article as in claim 44, the first portion and second portion differing in material density by a factor of at least about 1.5.

47. An article as in claim 44, the first portion and second portion differing in material density by a factor of at least about 1.7.

48. An article as in claim 44, the first portion and second portion differing in material density by a factor of at least about 2.0.

49. A system for microcellular blow molding, comprising:
extrusion apparatus including an extruder having an inlet designed to receive a precursor of polymeric microcellular material, constructed and arranged to provide a single-phase, non-nucleated solution of polymeric material and blowing agent, and a blow molding forming die fluidly connected to the extruder and having an outlet designed to release a parison of microcellular material, the apparatus including an enclosed passageway connecting the extruder inlet with the die outlet, the passageway including a nucleating pathway having length and cross-sectional dimensions selected to create in a single-phase, non-nucleated solution of blowing agent and fluid polymeric material a pressure drop at a rate sufficient to cause microcellular nucleation; and
a blow mold positionable to receive a parison of microcellular material from the die outlet.

50. A system as in claim 49, the nucleating pathway having length and cross-sectional dimensions such that, when fluid polymer is passed through the pathway at a rate of about 40 lbs fluid per hour, a pressure drop rate in the fluid polymer of at least about 0.3 GPa/sec is created.

51. A system as in claim 49, the enclosed passageway connecting the inlet with the outlet constructed and arranged to receive a blowing agent that is a gas under ambient

conditions and to mix the blowing agent with the precursor to form a single-phase, non-nucleated solution.

52. A system as in claim 49, wherein the nucleating pathway is constructed and arranged to nucleate microcellular material at a rate of at least about 60 lbs per hour.

53. A system as in claim 49, wherein the nucleating pathway is constructed and arranged to nucleate microcellular material at a rate of at least about 100 lbs per hour.

54. A system as in claim 49, wherein the nucleating pathway is constructed and arranged to nucleate microcellular material at a rate of at least about 400 lbs per hour.

55. A system as in claim 49, the die having an exit gap and being constructed and arranged to vary the size of the exit gap, during extrusion, to form an extrudate having a thickness that varies as a function of distance from the exit gap.

56. A system as in claim 49, the die constructed and arranged to vary the size of the exit gap without changing pressure drop rate to which a polymeric material/blowing agent mixture passing through the die is subjected.

57. A system as in claim 49, wherein the nucleating pathway has a cross sectional dimension that changes along its length.

58. A system as in claim 57, wherein the pathway decreases in cross section in a downstream direction.

59. A system as in claim 49, wherein the blow mold is constructed and arranged to form a blow molded, foam, microcellular, polymeric article.

60. A system comprising:
an extruder constructed and arranged to extrude polymeric foam precursor material;

an accumulator, associated with the extruder, able to receive polymeric foam precursor material from the extruder and to accumulate a charge of polymeric foam precursor material; and

blow molding apparatus positionable to receive a product of the accumulator, via a forming die, and constructed and arranged to blow mold the material to form a blow molded foam polymeric article.

61. A system as in claim 60, wherein the die includes a nucleating pathway having length and cross-sectional dimensions selected to create, in a single-phase, non-nucleated solution of blowing agent and fluid polymeric material, a pressure drop at a rate sufficient to cause nucleation.

62. A system as in claim 60, wherein the die includes a nucleating pathway having length and cross-sectional dimensions selected to create, in a single-phase, non-nucleated solution of blowing agent and fluid polymeric material, a pressure drop at a rate sufficient to cause microcellular nucleation.

63. A system as in claim 60, further comprising a die positionable to receive a product of the accumulator and to extrude a microcellular polymeric parison, and the blow molding apparatus is constructed and arranged to blow mold the parison to form a blow molded, foam, microcellular, polymeric article.

64. A system for microcellular blow molding, comprising:

an extruder having an inlet designed to receive a precursor of polymeric microcellular material, constructed and arranged to provide a single-phase, non-nucleated solution of polymeric material and blowing agent;

an accumulator positionable to receive polymeric foam precursor material from the extruder and to accumulate a charge of polymeric foam precursor material;

a blow molding forming die fluidly connected to the accumulator and having an outlet designed to release a parison of microcellular material; and

a blow mold positionable to receive a parison of microcellular material from the die

outlet and constructed and arranged to form a blow molded, foam, microcellular, polymeric article,

the apparatus including an enclosed passageway connecting the extruder inlet with the die outlet, the passageway including a nucleating pathway having length and cross-sectional dimensions selected to create in a single-phase, non-nucleated solution of blowing agent and fluid polymeric material a pressure drop at a rate sufficient to cause microcellular nucleation.

65. A method comprising:

extruding microcellular polymeric foam extrudate from an extruder die while varying the thickness of the extrudate.

66. A method as in claim 65, comprising providing a single-phase, non-nucleated solution of polymeric material and a blowing agent that is a gas under ambient conditions, nucleating the single-phase solution by subjecting the solution to a high pressure drop rate, and extruding polymeric foam extrudate that is a product of the single-phase solution.

67. A method as in claim 66, comprising extruding a microcellular parison suitable for blow molding.

68. A method as in claim 67, further comprising blow molding the parison to form a microcellular, blow-molded article.

69. A method as in claim 68, the article having a void volume of at least about 10%.

70. A method as in claim 65, comprising establishing a stream of a fluid, single-phase non-nucleated solution of a precursor of foamed polymeric material and a blowing agent, continuously nucleating the solution to form a nucleated polymeric fluid, and extruding the polymeric foam extrudate from the nucleated polymeric fluid.

71. A method as in claim 70, the step of continuously nucleating involving creating sites

of nucleation of the blowing agent in the stream by subjecting the stream to conditions of solubility change sufficient to create sites of nucleation in the solution in the absence of an auxiliary nucleating agent.

72. A method as in claim 65, comprising establishing a stream of a fluid, single-phase non-nucleated solution of a precursor of foamed polymeric material and a supercritical fluid blowing agent.

73. A method as in claim 70, involving creating sites of nucleation by subjecting the stream to a pressure drop at a pressure drop rate sufficient to create sites of nucleation.

74. A method as in claim 73, involving subjecting the stream to a pressure drop at a pressure drop rate sufficient to create sites of nucleation at a density of at least about 10^7 sites/cm³.

75. A method as in claim 73, involving subjecting the stream to a pressure drop at a pressure drop rate of at least about 0.3 GPa/sec to create sites of nucleation.

76. A method as in claim 65, comprising extruding polymeric foam extrudate into ambient conditions from an extruder die while varying the thickness of the extrudate.

77. A method as in claim 65, involving establishing the stream of fluid, single-phase non-nucleated solution of a precursor of foamed polymeric material and a blowing agent by introducing, into fluid polymeric material flowing at a rate of at least about 10 lbs./hr, a fluid that is a gas under ambient conditions and, in a period of less than about one minute, creating a single-phase solution of the fluid and the polymer, the fluid present in the solution in an amount of at least about 2% by weight based on the weight of the solution.

78. A method as in claim 77, comprising continuously nucleating the solution by continuously decreasing the pressure within successive, continuous portions of the flowing, single-phase stream at a rate which increases.

79. A method as in claim 78, wherein the concentration of the blowing agent in the homogeneous single-phase non-nucleated solution is at least about 5 percent, by weight, of the solution.
80. A method as in claim 65, wherein the concentration of the blowing agent in the homogeneous single-phase non-nucleated solution is at least about 7 percent, by weight, of the solution.
81. A method as in claim 65, wherein the concentration of the blowing agent in the homogeneous single-phase non-nucleated solution is at least about 10 percent, by weight, of the solution.
82. A method as in claim 65, wherein the blowing agent is supercritical carbon dioxide.
83. A method comprising:
providing a polymeric foam parison; and
subjecting the parison to blow molding conditions of at least about 15 psi thereby expanding at least a portion of the parison by at least about 50% in circumference and forming a blow-molded article, while maintaining a relatively unchanged density by increasing the density of the parison by no more than about 20% in going from the parison to the blow-molded article.
84. A method as in claim 83, wherein the foam parison is of void fraction of at least about 10%.
85. A method as in claim 83, wherein the parison is microcellular.
86. A method as in claim 83, wherein the parison has a pre-blown thickness of less than about 0.100 inch.

87. A method as in claims 83, further comprising extruding the parison from a mixture of polymeric material and blowing agent, the blowing agent present in the mixture in an amount less than about 3% by weight based on the weight of the mixture.
88. A method as in claim 87, comprising extruding the parison from a single-phase solution of polymeric material and supercritical blowing agent.
89. A method as in claim 88, wherein the blowing agent comprises carbon dioxide.
90. A method as in claim 88, wherein the blowing agent comprises nitrogen.
91. A method comprising:
providing an extruded polymeric microcellular foam parison; and
subjecting the parison to blow molding conditions.
92. A method as in claim 91, the subjecting step involving applying pressure of at least about 1.5 bar internal of the parison.
93. A method as in claim 91, involving applying pressure of at least about 3 bar internal of the parison.
94. A method as in claim 91, involving applying pressure of at least about 5 bar internal of the parison.
95. A method as in claim 91, involving applying pressure of at least 10 bar internal of the parison.
96. A method as in claim 91, involving forming a final blow-molded product that is essentially free of a supporting, non-foam structure, the article being essentially closed cell, having a wall thickness of less than about 0.075 inch.

97. A method as in claim 91, comprising continuously extruding polymeric foam extrudate and continuously subjecting the extrudate to blow molding conditions.
98. A method as in claim 91, comprising:
providing an extruded polymeric foam parison having a first portion and a second portion spaced from the first portion in the parison machine direction, the first portion and the second portion differing in thickness by a factor of at least about 1.1; and
subjecting the parison to blow molding conditions.
99. A method as in claim 98, the first portion and the second portion differing in thickness by a factor of at least about 1.3.
100. A method as in claim 98, the first portion and the second portion differing in thickness by a factor of at least about 1.5.
101. A method as in claim 98, the first portion and the second portion differing in thickness by a factor of at least about 1.7.
102. A method as in claim 98, comprising:
providing an extruded polymeric foam parison having a first portion and a second portion spaced from the first portion in the parison machine direction, the first portion and the second portion differing in material density by a factor of at least about 1.1; and
subjecting the parison to blow molding conditions.
103. A method as in claim 98, comprising:
providing an extruded parison of polymeric material of melt flow no more than about 0.2 g/10 min; and
subjecting the parison to blow molding conditions.
104. A method comprising:
providing a polymeric microcellular foam parison; and

without heating the parison subjecting the parison to blow molding conditions.

105. A method as in claim 104, wherein the parison is an extruded polymeric microcellular foam parison.

106. A method comprising:

extruding a polymeric foam extrudate from a extruder die in a machine direction while varying the temperature of the extrudate exiting the die thereby forming an extrudate having a first portion and a second portion spaced from the first portion in the machine direction, the first portion and the second portion differing in material density by a factor of at least about 1.1.

107. A method as in claim 106, comprising successively varying the temperature of the extrudate exiting the die via a cold gas stream.

108. A device comprising:

a polymer forming die including an inlet at an upstream end thereof constructed and arranged to receive a single-phase, homogeneous solution of polymeric fluid and blowing agent that is a gas under ambient conditions, an outlet at a downstream end thereof, defining a die gap, for releasing foamed polymeric material, and a fluid pathway connecting the inlet with the outlet, the fluid pathway including a nucleating pathway, the die constructed and arranged to vary the width of the die gap during extrusion while maintaining a constant nucleating pathway gap.

109. A device as in claim 108, the nucleating pathway having length and cross-sectional dimensions that, when fluid polymer is passed through the pathway at a rate greater than 40 lbs fluid per hour, creates a pressure drop in the fluid polymer of at least about 0.3 GPa/sec.